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COMPUTER-BASED GRAPHIC SIMULATIONS FOR TACTICAL COMMUNICATIONS --ETC(U)
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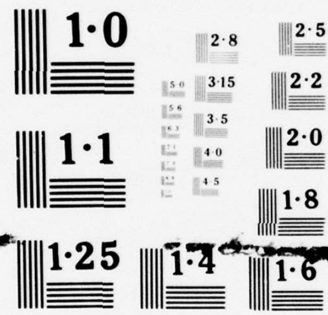
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COMPUTER-BASED GRAPHIC SIMULATIONS FOR TACTICAL COMMUNICATIONS TRAINING

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COMPUTER-BASED GRAPHIC SIMULATIONS FOR TACTICAL COMMUNICATIONS TRAINING

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The research investigated the use of two-dimensional simulations of the controls and displays of an antisubmarine warfare jet. The purpose was to examine the use of the simulation methodology for training performance skills. The results showed that students liked the training and felt that it had been effective in helping them master the requisite skills. An evaluation by fleet-experienced operators supported these findings. Features of the computer-based

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training system were discussed, and recommendations for needed research were made.

FOREWORD

This research and development was conducted in support of Navy Decision Coordinating Paper Z0108-PN, Education and Training Development (NDCP-Z0108-PN), under the sponsorship of the Chief of Naval Operations (Director of Naval Education and Training). It was accomplished under subproject Z0108-PN.30A (Adaptive Experimental Approach to Instructional Design). The overall objective of the subproject is to develop an empirically-based instructional design system to aid developers in deciding on instructional alternatives based on cost benefits and resource limitations.

The cooperation and assistance of personnel at Fleet Aviation Specialized Operational Training Group, Pacific Fleet are recognized and appreciated. CDR Bruce Churchill made particularly invaluable contributions as subject matter expert. The help of the computer programmers, Mr. Robert Padilla and Mr. Anthony Sassano, is also gratefully acknowledged.

The results of this study are intended for use by the research and development community. In addition, based upon the findings and conclusions of work efforts on low cost part-task training using interactive computer graphics, specifications will be developed and recommended for incorporation into the planning and design of future aircrew training systems and simulators.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

Typically, performance skills training in the military is carried out on high fidelity simulators. Since there is little evidence that might suggest a less costly alternative, this approach has been used to ensure maximum transfer of training. Working from the premise that high fidelity is not always necessary for effective training, the present research investigated the use of computer-based simulations for low cost performance skills training.

Purpose

This effort was designed as a follow-on to a study that demonstrated the feasibility of using graphic simulations presented on a computer-based training (CBT) system to teach procedural and simple perceptual motor skills. The intention was to extend the generality of the previous findings by testing the effect of the methodology for training complex perceptual motor skills. The examination of the feasibility of using software to "link" two or more computer terminals so students could practice simulated interactions of operators in patrolling aircraft was also of interest.

Approach

CBT materials were designed to train students to operate the S-3A Data Link 11 communications system. Graphic displays of the functions and appearances of the necessary controls and displays were presented to students on the PLATO IV CBT system. The materials include segments for practice, review, and a dynamic tactical scenario. Instruction and feedback were programmed where appropriate. Pairs of students interacted with these materials and then responded to a questionnaire that was developed to assess student impressions of this application of CBT. Expert opinion was solicited from fleet-experienced operators regarding the training value and simulation fidelity of the lesson materials.

Findings

Results showed that students liked the use of computer-based simulations for training, and that they perceived that the training had been effective. It was also found that system communication line errors were a major source of annoyance for students, and that these students were less tolerant of CBT system features than students in the previous study. Although experienced operators stated that the training lesson would be helpful in learning the Data Link operations, they were critical of the use of the copilot panel and the slow display response times. Cost considerations and potential implications on fleet readiness were discussed.

Conclusions

It was concluded that the use of interactive computer graphics for simulating two-person mission operations was a feasible training methodology. This application of CBT allowed students to practice tasks that could otherwise be practiced only in the operational situation.

This technology could potentially serve as a low cost capability for shore-based training in areas where the alternatives are either (1) little or no training, or (2) use of high fidelity simulators or operational equipment.

Recommendations

Additional research and development should be performed (1) to investigate the use of stand-alone terminals for computer-based simulation, (2) to obtain longitudinal and transfer data, (3) to examine the effects of previous training and type of skill being trained, and (4) to determine and investigate areas of training for implementation of new, more effective technologies.

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INTRODUCTION

Problem

Since large numbers of military personnel are assigned to training programs each year, the Navy has a vested interest in the research and development of efficient training technologies. Research at the Navy Personnel Research and Development Center (NAVPERSRANDCEN) has been directed toward the development of procedures for adapting instruction to individuals while maintaining cost effectiveness. One instructional methodology that has received much attention is computer-assisted instruction (CAI), sometimes called computer-based training (CBT). It has been shown that this methodology provides effective and efficient training. For example, Ford, Slough, and Hurlock (1972) reported an average training time savings of 47 percent for CAI as compared to other instructional methods that were investigated. Until recently, however, the bulk of CAI or CBT research has examined only the use of the computer for teaching cognitive skills, such as math. The successful application of this methodology to training performance skills, such as operation of equipment, could produce considerable financial savings in Navy training programs.

The fact that performance skills training is particularly costly for the Navy may be a result, at least in part, of the state-of-the-art in simulation. These training programs usually require students to have hands-on practice with actual equipment or high fidelity simulators to learn even the simplest performance skills. Program designers generally prescribe this method because the salient transfer of training variables is unknown. In other words, since the program designers do not know the minimum fidelity requirements for a training device, they assume that the best way to provide instruction is to use a device that is as similar to actual equipment as possible. While numerous researchers (e.g., Cream & Lambertson, 1975) have suggested that the use of high fidelity devices is not always necessary for training, there are still very few solutions offered in the way of alternate training methods.

Purpose

The present research effort was designed as a follow-on to an earlier study (Crawford, Hurlock, Padilla, & Sassano, 1976), which demonstrated the feasibility of using interactive computer graphic simulations of operational equipment for part-task training of performance skills. To extend the generality of these findings, the present research employed this methodology to train S-3A Tactical Coordinators (TACCOs) to operate the Data Link 11 system. The Data Link is a communications system that involves the participation of operators in several aircraft interacting with their equipment and each other. Unlike the previous research, relatively complex perceptual motor skills are required to operate Data Link; this training represents an advanced phase of instruction for S-3A TACCOs.

There was a dual interest in the present research: (1) to determine if computer-based simulations could be used as a part-task training device for teaching perceptual motor skills, and (2) to examine the feasibility of elaborating on the methodology by using software to "link" two or more CBT terminals in order to simulate interactions between two or more aircraft.

If effective training is demonstrated in this project, several products are expected. One benefit would be to expand the existent data base of fidelity literature by showing that perceptual motor skills can be taught with low appearance and high operational fidelity simulation. Another would be the development of a dynamic, low cost training capability for Data Link in ground training. Tactical officers seldom have the opportunity to practice these skills until they are in an operational S-3A in the fleet. Finally, it is expected that, if computer terminals can be "linked" to provide interactive simulations for two or more persons, a new and potentially beneficial use of CBT will have been demonstrated.

Background

In a recent research effort at NAVPERSRANDCEN, the training and cost effectiveness of teaching procedural and simple perceptual motor skills with computer-based simulations were compared to that of a conventionally used method (Crawford et al., 1976). Copilots in their first week of S-3A training were compared on their ability to utilize an operational panel, the Integrated Control System, after training with one of the two instructional methodologies. The conventional methodology required that students study a workbook for 8 hours and then undergo a 1-hour hands-on practice with a high fidelity position trainer under the guidance of an instructor. The CBT group practiced for 3 hours with two-dimensional graphic simulations of the panel and a multipurpose display that were presented to them via the PLATO IV instructional system. These materials were created by software that simulated the appearance and all functions of the controls and display. The simulations were presented with instruction and feedback and designed to elicit maximum student-system interaction. Student input was registered for computer evaluation when the student pointed at a touch-sensitive front panel on the PLATO IV terminal. Specifically, when the student touched the graphic simulations, the components and display (including tactical symbology, readouts, alerts, and tableaus) reacted similarly to actual equipment. Additionally, the computer evaluated the input and gave the student feedback.

Analysis of the experimental data showed that CBT resulted in mastery of the requisite skills and that considerable cost avoidance could be achieved by substituting it for the conventional method in this phase of S-3A copilot training. Estimates of additional savings that could be obtained if the CBT system were utilized on a full time basis for S-3A training made it worthwhile to pursue this investigation further.

A related study has come to the attention of the authors since the execution of the present effort. It will be summarized here since it is pertinent to the discussion of the present results. Trollip (1977) demonstrated that students could learn to fly holding patterns by CBT. Like the present authors, Trollip was interested in the investigation of CBT for skills training. Displays of instruments were presented on a PLATO IV instructional system, and a "Joystick" was interfaced with the computer for simulated flight. Students were able to practice "flying" holding patterns under different conditions as shown on the simulated indicators. After each practice, graphic representations of the "flown" pattern and the ideal pattern were displayed with diagnostic feedback.

Students were trained by either PLATO or a lecture, and all were given additional training on a simulator and a performance test. Results showed that the PLATO simulations had provided effective training. The author concluded that complex procedural skills can be taught by a computer when the necessary cues are simulated.

METHOD

Subjects and Advisors

Twenty-two male S-3A Tactical Coordinator (TACCO) trainees at the Fleet Aviation Specialized Operational Training Group Pacific Fleet (FASOTRAGRUPAC), Naval Air Station, North Island participated in the study. These men, who were in their sixth week of S-3A training, served as subjects as part of their course work.

Six experienced TACCOs were solicited for their opinions about the PLATO Data Link lesson. Two of these officers were TACCO instructors and familiar with the PLATO lesson. The others had just returned from deployment and volunteered to go through the PLATO lesson as "students." The background of the experienced TACCOs Data Link training consisted of 3 to 15 hours of combined lecture/workbook instruction. During fleet deployment, they averaged two or three flights per week and attempted Data Link operations during most flights.

Apparatus

Subjects received their training from the PLATO IV instructional system, which is under the control of a CDC Cyber 73 computer. Data are transmitted between the computer and remote student terminals by voice grade telephone lines. Each terminal has a 64-character keyboard and an 8-1/2 inch square plasma display panel. The terminals were located in individual carrels at the FASOTRAGRUPAC building.

The terminals used in this research were additionally equipped with touch panels that enabled students to enter data into the computer by pointing at any of the 256 programmable areas of the plasma panel. The touch panel consists of a thin framework that is substituted for the normal metal front frame of the PLATO IV terminal. It contains the necessary electronics (scanning system, infrared light emitters and detectors, control logic, and cable to connect with the terminal connector) to permit the panel to operate as an auxiliary input device. The light emitters and detectors are evenly-spaced in a 16 x 16 array. The invisible paths formed by the light rays across the exterior surface of the plasma panel describe a checkerboard-like array of 256 1/2-inch square points that may be selected by the student. Inputs are sensed by the system when the beams of light emitting from the X and Y axes are broken simultaneously by the student's pointing responses.

Training Materials

The materials were designed to train students to use the S-3A Data Link 11 system. Instruction, feedback, definitions of terms, and functions and appearances of necessary controls and displays were presented to students on the PLATO IV instructional system. The PLATO IV computer was programmed to present these materials in response to student input through the touch panel or keyboard, and to evaluate student performance when appropriate. Pairs of student terminals were "linked" by software so that students could simulate tactical interactions as operators in separate S-3As on patrol. Detailed descriptions of the actual Data Link system and of each component of the training materials are presented in the following paragraphs.

Data Link System

The Data Link system is a computerized communications system that, in effect, unites all S-3A mission patrol units into a single antisubmarine warfare searching entity. Following launch from a carrier, the S-3A Picket Unit (PU) flies to an assigned operations area where it patrols to detect, track, and possibly destroy hostile targets. The TACCO in each patrolling S-3A must make tactical decisions, based on the premission briefing and the current tactical situation. He must decide which contacts, of the many that are continually appearing on his Multipurpose Display (MPD), to store on the Data Link net. The TACCO carries out complex interactions with the components of the Integrated Control System (INCOS) in order to store contacts on the net, to keep them up-to-date, and to perform associated tactical operations. Once a contact is on the net, it becomes part of the whole tactical picture (as opposed to a small part corresponding to one individual's search area), which can be seen on the displays of the other patrolling TACCOs and the Net Control Station (NCS) on the carrier.

Data Link operations begin with the launch of several S-3As from a carrier. These crafts then fly to an area to relieve other patrol units already on-station. The premission brief provides each TACCO with information on destination, procedures, and any special instructions. Enroute to the operations area, each TACCO initializes the hardware in his aircraft as a preparation to joining the Data Link net, and registers any contacts picked up on the way out. Once on-station, the TACCO configures the hardware to receive a data dump of all tactical data acquired by the unit already on patrol. Following this dump, the relieving unit configures the hardware again in order to join the Data Link net as a participating unit. As a participating unit, the TACCO then directs his aircraft around the assigned area, picks up new contacts, keeps old contacts up-to-date, and follows specified net reporting procedures.

Throughout the procedures described above, the TACCO interacts and receives feedback from the NCS, the copilot, the sensor operator, TACCOs in other units, and his equipment. For example, the computerized equipment gives him feedback in the form of readouts regarding incorrectly configured hardware, and the NCS sends out instructions that need to be acknowledged and carried out. In the computer-based simulation to be described here, these procedures and interactions were reproduced to simulate a realistic tactical mission.

The simulation was conceptualized as a two-part effort for the trainee: (1) configuration of hardware and all operations up to the point at which the aircraft joins the net as a participating unit, and (2) participation in a simulated mission. Training behaviors required for the first category are very straightforward since student performance must be evaluated either as correct or incorrect. However, few guidelines currently exist for evaluating student performance in the second category of behaviors. The first phase of the simulation, then, was considered as a training segment. In this segment, records were kept by the computer,

which gave the student extensive feedback. While some feedback was given in the second segment, this phase was designed as a practice vehicle for students and as a means by which the technical feasibility of this type of simulation could be examined.

Premission Brief

A brief sheet that is similar to those used for actual missions was used for the computer-based simulation. The brief included such information as which unit to relieve, other units on patrol, parameters to use for various operations (e.g., radio frequency for the data dump), and all net reporting procedures.

Introduction and Glossary

An on-line introduction was presented to give the student an orientation to the training objectives of the simulation materials. Information was also provided on the use of PLATO IV. The student was given practice using the touch panel, and instructed on how to use the keyboard to enter or exit at any point in the lesson.

A glossary was always available for the student's use. It contained terms that the student had been previously exposed to, but that might be useful for review. The glossary was programmed so that the student could select a term and the definition of it would be presented on his display.

Integrated Control System and Multipurpose Display

The actual Integrated Control System (INCOS)) panel consists of a series of rotating matrices of system option switches, display scale switches, numeric switches, and a trackball. The computer-based simulation of the panel was an accurate two-dimensional representation including the capability to display 324 different switch labels that changed as a result of student touch panel input (see Figure 1). Programmed logics also enabled the color patterns of the switches to change when appropriate to indicate various options (i.e., "not available," "available," or "active"). The trackball caused a cursor to move across the Multipurpose Display (MPD) when touched repeatedly on the area which corresponded to the desired direction of movement of the cursor.

The MPD, which was always presented on the PLATO screen with the INCOS panel, was the area in which all symbology and tactical actions were displayed. Using the panel, the student could create symbology, see all air and surface crafts moving, measure distances, and cause numerous other events to occur that would all be seen on the display, as in an operational S-3A.

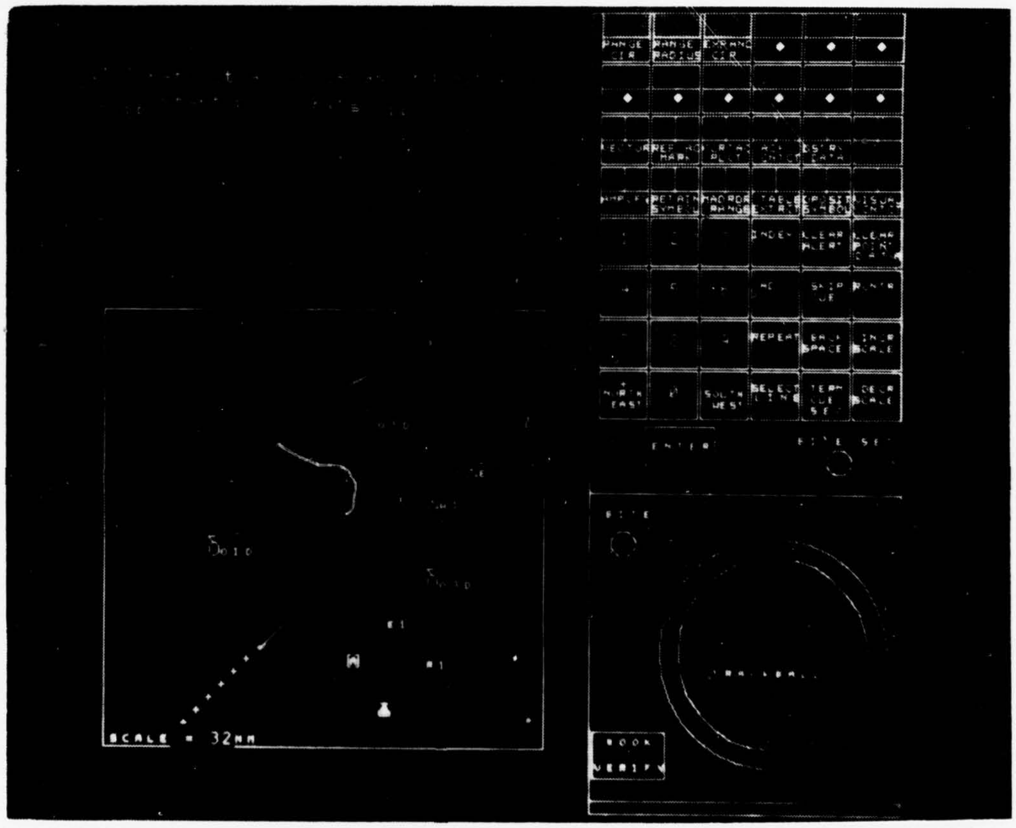

Figure 1. Computer-based simulation of the Integrated Control System (INCOS) panel.

The panel and MPD were available in two separate sections of the simulation materials. In one section, this equipment was presented for non-structured practice. For example, the student could practice configuring hardware for some phase of operations and would get dynamic reactions from the panel and MPD but without feedback. In the second section, the simulated equipment was available for use in the scenario. At this point, the student would freely interact with the equipment while the programmed scenario was causing symbology to move and messages and alerts to come from the Net Control Station (NCS) and other sources.

Scenario

The scenario began with instructions to the student to initialize his hardware to join the Data Link net and to configure to receive a data dump from the Picket Unit (PU) on-station. These procedures required simulated interactions with equipment and verbalizations with the NCS. When tasks were completed, the student's MPD became filled with the tactical data picked up by the on-station unit. Students at separate PLATO terminals participated in the scenario in pairs, so each student was receiving similar information concurrently. The total simulated mission area was 2048 x 2048 miles. This was divided into four possible patrol areas of 1024 x 1024 miles each. All tactical symbology conformed to this scale such that when a student increased his display scale to see the area beyond his, the display reflected the symbology in another PU's area. Once two students had successfully joined the net, they could interact with each other and see the results of these interactions on their MPDs.

As PUs on the simulated mission, the students would begin by dropping fly-to-points to steer their aircrafts in some logical pattern (in this case, the brief instructions were to fly a "ladder" pattern) around the operations area in search of contacts. Eighteen contacts were programmed to be "hidden" in each student's operations area. Each contact would be picked up as forward looking infrared (FLIR), radar, or visual. When the student had his aircraft within 25 miles of a contact, he would see it on his screen as a radar fix. The contact appeared as either (1) friendly, unknown, or hostile, and (2) surface, subsurface, or air. The student could then "fly" his craft closer to the contact; once he was within 12 miles, the contact would show up as a FLIR fix. To get a visual fix on a contact, the student had to have his aircraft within 2 miles of it. The premission briefing had instructed the student to report any unknown or hostile contacts to the Data Link net, and to cease report on contacts that were classified as friendly. The computer recorded the student's net reporting procedures, and his responses to alerts and orders. Minimal feedback was provided for the student in this section.

Student Questionnaire

Since a ground capability for Data Link training does not exist, a questionnaire was developed to determine student impressions of the CBT experience. Items on the questionnaire were specifically designed to elicit responses about the PLATO IV system, the Data Link training materials, and CBT as a mode of instruction. Student feelings regarding acceptability and perceived effectiveness of the training were of major interest.

Procedure

All students (N = 22) practiced with the simulation materials on PLATO IV for 2 hours. As pairs of students reported for training, each was asked to sit at a PLATO IV terminal and read the premission brief sheet. Each student signed onto PLATO IV and began to proceed through the materials. The order in which most of the materials were presented was determined by student control, although it was necessary for two students to interact with the scenario segment at the same time. Following PLATO IV training, all students responded to the questionnaire. The experienced TACCOs responded to a short questionnaire and were interviewed by the experimenters to obtain their opinions and reactions regarding the PLATO lesson.

RESULTS

All responses to the student questionnaire are presented in the Appendix and summarized in the following paragraphs. Open-ended questions were content-analyzed by two raters and an inter-rater reliability measure of 85 percent was obtained.

PLATO IV Ratings

Questions 1 through 6 asked students to rate the PLATO system on operational characteristics such as ease of "signing-on," readability of the display, etc. As shown in Table 1, three-fourths of the students rated the system favorable.

Table 1

Mean Percentages of Responses to PLATO IV Questions (N = 22)

Rating	Mean Percent
Very Favorable	22
Favorable	53
Neutral	19
Unfavorable	4
Very unfavorable	2

Training Materials Ratings

Questions 7 through 14 asked students to rate the training materials. Questions on the Data Link system itself asked students to indicate: (1) the extent to which it had helped their understanding of the basic skills, (2) why they felt it had or had not been effective, and (3) how they thought it would affect their performance in the fleet (Nos. 7, 8, and 11, respectively. Responses showed that this new training mode was perceived as helpful to a "great extent" by 50 percent of the students, and to "some extent" by 41 percent. Most students (84%) felt that it was effective, primarily because it allowed hands-on practice. The reasons why students felt the courseware was (or was not) effective are shown in Table 2.

Table 2

Reasons Given as to Why Training Was (or Was Not) Effective

Student Comment	% Student Response
No response	.04
It was not effective because it lacked realism	.12
It was effective - miscellaneous reason	.20
It was effective because it allowed visualization of operations	.24
It was effective because it allowed hands-on practice	.40

Regarding the effect of the training on their later performance, most (86%) of the students reported that the experience would make it easier to learn the skills when using actual S-3A equipment; and 14 percent, that it would enable them to operate the Data Link system.

Students were asked how they felt about the effectiveness of interactive graphic simulations and feedback in training (questions 9 and 10). As shown in Table 3, all of the students rated the graphic simulations as either "very favorable" or "favorable," compared to 72 percent for feedback.

Table 3

Percentage of Student Ratings Assigned to Two Training Features

Rating	Interactive Graphic Simulations	Feedback
Very favorable	.09	.09
Favorable	.91	.63
Neutral	.00	.23
Unfavorable	.00	.05
Very unfavorable	.00	.00

Student responses to questions concerning what they liked best and least about the training materials are given in detail in the Appendix under questions 12 and 13. In summary, the most-liked features were the hands-on practice capability (38%) and the fact that they were able to see a representation of the equipment operations (19%). The least-liked features were system or software problems (38%) and delays or slowness

in the construction of graphic displays (23%). (Software or system problems, here and in other questions, refers to system interruptions, transmission errors, student backouts caused by a heavy user load, and problems with the touch panel caused by the small size of the touch points.)

In response to the question asking for their opinion on how the training could be improved (No. 14), 36 percent suggested eliminating system or software problems. No other common answers were given to this question.

CBT Ratings

Questions 15 through 19 asked the students to rate CBT. In reporting attitudes about CBT as compared to other types of training (Nos. 15 and 16), the majority of the students rated it either as "enjoyable" (67%) or "very enjoyable" (28%), and as "outstanding" (67%) or "above average" (19%).

Some of the characteristics students reported they liked most about CBT (No. 17) were self-paced instruction (29%), instructional characteristics such as feedback (21%), the novelty (14%), and the capability for hands-on practice (14%). The least-liked features of CBT (No. 18) reported were that it was tiring or boring (36%) and had system or software problems (23%).

Question 19 asked students to make a judgment as to how much value the training would have for new inexperienced students. Over half (59%) said it would have "much value"; and 27 percent, "moderate value."

The last question (No. 20) asked the students for any final comments. Most (73%) students did not respond; 27 percent made miscellaneous comments that generally referred to their entire training experience rather than just the PLATO segment.

Expert Evaluation

The six experienced TACCOs were asked to compare the usefulness of lecture/workbook instruction to PLATO training for helping a new TACCO to operate Data Link during fleet deployment. On a scale of 0 to 10, where 0 = No Help, 5 = Moderately Helpful, and 10 = Extremely Helpful, they gave lecture/workbook instruction an average rating of 4.7; and PLATO, 6.7. Only one TACCO rated PLATO below 6, while half of the TACCOs rated the lecture/workbook instruction 2 or below.

The most frequently (N = 3) mentioned criticism of the PLATO lesson and scenario was that the graphic display rewrite and keyboard response times were slower than real time. The other most common criticism (N = 3) was that the scenario was too complex, having too many targets and sightings displayed at the same time.

Advantages of the PLATO training most often listed, included: (1) active participation by the trainee (N = 3), (2) extensive help and instruction available (N = 3), (3) self-paced instruction (N = 2), and (4) capability for students to do "dump" operation (N = 2).

Suggestions for improving the PLATO lessons included (1) using the TACCO hardware configurations for the graphic displays, instead of the copilot INCOS panel, and (2) placing less information in the scenario displays.

DISCUSSION

The use of interactive computer graphics for simulating two-person mission operations was shown to be a feasible methodology for part-task training. Students were able to participate in simulated operations of TACCOs on patrol through computer terminals "linked" by software. Overall indications from students were that the methodology was effective for training the perceptual motor skills required for Data Link operations. This successful application demonstrates the feasibility of CBT as a potential partial alternative to costly high fidelity simulators. Student impressions and cost considerations will be discussed in the following paragraphs.

Student Acceptance

Student attitudes were quite favorable towards the Data Link training experience. They liked the PLATO system, the training materials, and the mode of instruction. Specifically, students made positive comments about the interactive computer graphics. They said that these helped the training process by allowing hands-on practice and/or visualization of equipment and mission operations. They also liked the self-paced instruction and feedback.

Despite students' overall positive attitude toward the training, one problem that elicited negative comments (during training as well as on the questionnaire) concerned system interruptions. These interruptions were usually caused by transmission errors on the phone line that connects the terminals in San Diego to the computer at the University of Illinois. This type of error distorts the graphic display and requires the generation of a new display. This, in turn, often meant that the student had to wait for the new display and then repeat a portion of the training segment that had previously been near completion. It was observed that this frustrated students and caused a severe disruption in the continuity of the learning process. Whether student acceptance of these circumstances could be sustained over an extended period of time is questionable. The problem of communication line errors should be considered in future planning. One solution would be the use of stand-alone terminals because they require no communication line hook-ups.

Students also indicated some problems with readability of the graphic displays. To display the entire INCOS panel on one screen, it was necessary to use small characters for the switch labels (see Figure 1). This suggests that, when designing graphic simulations, considerable attention should be given to determining the size of the alphanumerics that will ensure readability. Certain types of equipment, due to size or detail, may have to be simulated in portions to overcome this type of problem.

It is of interest to note that, when the same simulated panel was used in previous research (Crawford et al., 1976), the students had fewer complaints than did those in the current study. The basic differences between the two studies are summarized in Table 4.

Table 4

Comparison of Two Computer-based Simulation Studies

Study	Operator position of trainee	Hours spent in hands-on practice with high fidelity trainer prior to CBT	INCOS panel simulated	Level of training	Skills trained
Crawford, Hurlock, Padilla, & Sassano, 1976	Copilot	Ø	Copilot	Early familiarization	Procedural and simple perceptual motor
Crawford, Hurlock, & Rogo, 1977	TACCO	18	Copilot[a]	Advanced	Complex perceptual motor

[a]The TACCO position has a different configuration of the INCOS panel than that of the copilot position.

Because the training effectiveness was tested and evaluated to have been high in both studies, fidelity of the simulation per se does not seem to offer a logical explanation for the more critical attitude of the TACCOs. A more plausible interpretation may be that the TACCOs were less tolerant of fidelity limitations and CBT system features, such as line errors, because of their background with the high fidelity position trainer. Another possibility may be an effect caused by the interaction of background with the advanced nature of the skills being trained. For example, a student who has spent considerable time on the position trainer may be more impatient with fidelity limitations when he is being required to learn complex skills than when he is learning more simple tasks.

Training Effectiveness

Students perceived that the training was helpful for learning the prerequisite skills, and that it would enhance their performance in the operational situation. These results, in conjunction with those discussed earlier (Crawford et al., 1976; Trollip, 1977), indicate some of the possible factors responsible for the effective application of this methodology for part-task training.

The use of computer-based simulations may represent the best of both worlds of simulation and CBT. The methodology permits the student to have hands-on interactions with visual representations of operational equipment while concurrently receiving instruction and corrective feedback. Any instructional features, such as self-paced learning materials, may also be incorporated into these simulations. CBT usually requires less student learning time than conventional methodologies, and the need for an instructor is eliminated since the computer can record and evaluate student responses as well as present instruction and feedback. Thus, the dynamic features of simulation that permit the student to actively respond are combined with the efficient and instructionally beneficial characteristics of CBT.

The present authors make the assumption that, for most military training, the appropriate emphasis in the design of a training device should be on the manner in which that device is to be used rather than on its physical similarity to actual equipment. Specifically, active responding, feedback, self-pacing, and other established learning principles are considered to be crucial to the success of the learning process. This assumption may break down at the level at which gross motor skills are to be trained. However, teaching this type of skill is not usually the case in military training. Rather than learning to press a button, the student is more often learning some cognitive process that will lead him to press a button in order to achieve some desired result.

Trollip (1977) also attributes much importance to the design of the instructional materials in his simulations. He states that his experimental results support the idea that, for some kinds of training, simulation of the necessary cue, rather than simulation of a physical environment, may be advantageous. He also emphasizes the importance of the role of part-task training as contributing to effective learning with computer-based simulations. He notes that the student can practice the skills for the particular task being trained without distraction from irrelevant stimuli.

Expert Evaluation

The evaluation of the PLATO lesson by experienced TACCOs was almost identical to that given by TACCO students. The "experts" felt that the PLATO lesson was useful for preparing students for fleet deployment and operation of the Data Link.

Their criticisms and suggestions for improving the PLATO lesson further support the conclusion that, as experience with actual equipment increases, student and instructor tolerance and acceptance of lower fidelity training devices decreases. This appears to be true independent of training effectiveness of the instructional method. For instance, all but one of the experienced TACCOs complained that the copilot INCOS keyboard was used instead of the TACCO keyboard. On the other hand, no student complained about this.

Cost Considerations

Previous research (Crawford et al., 1976) reported that a cost avoidance of $44,000 per year could be accrued by the S-3A training community if PLATO IV terminals and training materials developed by NAVPERSRANDCEN were operationally implemented in place of the conventional training program. Since the materials represented only an 8 percent utilization of time available on the PLATO terminals, it was further predicted that a $500,000 yearly cost avoidance would be possible if maximum terminal utilization was achieved. This assumed that additional courseware would be comparable in cost effectiveness. Since the present effort represents new PLATO training for the same group, it is of interest to bring the cost figures up to date.

FASOTRAGRUPAC has continued to use the previously developed INCOS copilot materials for experimental training while the PLATO terminals were still on the site for the Data Link research. In fact, they have increased this usage by 2 hours to provide a "review" for the men returning from 10 weeks of training in other operations. This review previously consisted of 4 hours of workbook study and 1 hour of instructor-guided exercises in the position trainer. The increased usage changes the potential cost avoidance for copilot S-3A training.

At this time, there are new figures available for estimating PLATO costs. A four-terminal configuration currently costs $47,784 for 1 year. This total includes a 10 year amortization of the terminal purchase cost ($4,200), computer time sharing ($37,400), and terminal maintenance ($6,144). If the total yearly cost is divided by the total number of hours the four terminals can be used (8000), the resulting delivery cost is about $6 per hour.

A new figure for potential cost avoidance, which would include the additional 2 hours utilized for review purposes, requires examination of all the costs involved in both the PLATO training and the conventional program that it would replace. These costs are presented in Table 5, which shows that the cost difference is $345 per student. Thus, for 200 students trained per year, the total cost avoidance would be $69,000. This training represents a 45 percent utilization of available terminal time.

Table 5

Cost Per Student of Conventional and PLATO Methodologies for One Training Program

Item	Cost ($)	Total ($)
Conventional Training		
Personnel Costs		
12 hours student workbook study @$29 per hour	348	
2 hours student time in position trainer exercise	58	
2 hours instructor time in position trainer exercise @$29 per hour	58	
Position Trainer Costs		
2 hours @$28 per hour	56	
TOTAL		520
PLATO Training		
Personnel Costs		
5 hours student time	145	
PLATO Costs		
5 hours @$6 per hour	30	
		175
TOTAL		345

The nature of Data Link training inhibits cost comparison since students do not usually have the chance to practice these skills prior to deployment. On occasion, students were able to sit in a stationary S-3A and practice linking with simulated equipment in a local Navy lab. The cost of operationalizing the necessary systems in the stationary aircraft is $160 per hour. This comparison is inadequate, however, since the rare availability of time and functioning hardware made the probability of students receiving this training very low. From the standpoint that existing copilot INCOS training materials on the PLATO system already hold the potential for yielding $69,000 per year cost avoidance, there would be no additional cost incurred with the implementation of the Data Link materials.

Usage of the Data Link training program brings current terminal utilization to 57 percent. While it is possible that maximum terminal utilization could produce the kind of significant savings that have been mentioned above, it will probably have to be realized in new training programs. To talk of implementation of new methodologies in an on-going program, such as S-3A training, is an oversimplification of the issues. For example, this does not consider the dollars already spent on high fidelity simulators that were determined as necessary in the original analysis of S-3A training requirements. The magnitude of the costs involved prohibits major changes at this point in time. Thus, research that shows where high fidelity simulators can be replaced by less expensive devices will have a more significant impact in the design of future training programs.

Additional Training Benefits

A final note regarding cost considerations is the recent development of low cost, stand-alone, intelligent terminals. Where only a few terminals are required for a training application, delivery of CBT by this method may be much more cost effective than leasing computer time for a vendor's large network system. All alternative systems should be compared when making an implementation decision.

It is important to examine some of the less tangible features of the training described here--features that relate to increased effectiveness in present as well as in future training. If these characteristics can lead to improved fleet readiness, and there is reason to think they can, then they should be given primary consideration. The basic issue is the importance of shore-based vs. fleet training. It seems reasonable to assume that students who have had the chance to practice required operations on the ground at school may be better trained than those who have had to learn while airborne in the fleet. Once a man is in the air, it is unlikely that he will have time to practice a part of his job (e.g., Data Link operations) independently of his other tasks. He is then subject to distractions, pressures, and the lack of corrective feedback, which he would not experience in shore-based training.

Correct operation of the Data Link system, like other jobs that are active defense functions, is crucial to the success of the mission. There are probably many other similar training areas that could benefit from practice before deployment. With the increasing sophistication of technologies such as computer-based simulation, these training needs should not be ignored. The research community should continue to take responsibility to research, design, and help implement technological developments that could result in improved efficiency in a multitude of Navy jobs.

CONCLUSIONS

Students liked the CBT and felt that it was effective in teaching them the requisite skills for Data Link operations. This particular application of CBT allowed students to practice tasks that would otherwise be carried out in the operational situation. Thus, a ground training capability has been developed where none existed, and, in doing so, the feasibility of a unique application of CBT was further established. While additional data is desirable (e.g., transfer data), the potential effectiveness and efficiency of this kind of low appearance fidelity methodology has been demonstrated.

The cost benefits to be accrued, particularly the potential training benefits discussed, suggest that it will be advantageous to do further research. It will be necessary to develop criteria to identify those training situations that will most benefit from the implementation of computer-based simulations for training performance skills.

RECOMMENDATIONS

Recommendations for future research are made with three goals in mind: (1) the advancement of a promising technology, (2) the development of capabilities to retrofit on-going training programs, and (3) the development of specifications to incorporate these capabilities into future training programs.

The following recommendations are made:

1. Computer-based simulations should be programmed on stand-alone terminals and evaluated. This would eliminate the major problem of system interruptions and provide data for a cost analysis that could be compared to the figures obtained for use of a network system such as PLATO IV.

2. Data should be obtained that show transfer effects from computer-based training to the operational situation. It has been shown that low fidelity simulations are less expensive and provide training as effective as that carried out on actual equipment. However, it is not known whether or not there is any degradation in performance over time.

3. The present research indicated the need to examine the effects of student sophistication (i.e., amount of previous training) and type of skill being trained as these relate to student acceptability, fidelity of training device, and training effectiveness of computer-based simulations.

4. Empirical comparisons of shore-based and fleet training, in terms of effectiveness, are necessary. These could lead to firm recommendations for implementation of training technologies such as the one described here.

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APPENDIX

RESPONSES TO STUDENT QUESTIONNAIRE

RESPONSES TO STUDENT QUESTIONNAIRE

Questions 1-6 relate to PLATO IV characteristics; questions 7-14, to perceived effectiveness of the Data Link training materials; and questions 15-20, to opinions of CBT in general. Data for the objective questions are based on 22 student responses, while the N varied from 22 to 28 on the open-ended questions since more than one student response was allowed per question.

The percentage of students who responded to the various alternatives to questions on PLATO is shown in the table following those questions. The percentage of responses to alternatives to all other questions is listed after each question.

PLATO IV Ratings

1. Did you have any problems or interruptions with the system while proceeding through the training materials?

2. Did you have any problems using the touch panel?

3. Did you have trouble figuring out what to do next when you weren't told by the instructor?

4. Did you have "signing-on" or keyboard problems with the terminal?

5. Were the words, drawings, and figures difficult to see or read?

6. Did the delay in having to wait for new displays to fill the screen disrupt the continuity of the lesson?

Rating / Question	1	2	3	4	5	6
Never		.23	.05	.64	.14	.27
Seldom	.45	.68	.64	.27	.58	.54
Frequently	.41	.09	.31	.09	.09	.14
Usually	.09				.14	
Always	.05				.05	.05

Training Materials Ratings

7. To what extent do you feel that this new training mode helped your understanding of all basic Data Link skills?

a.	To a very great extent.	.05
b.	To a great extent.	.50
c.	To some extent.	.40
d.	To a little extent.	.05
e.	To a very little extent.	.00

8. Why do you feel the training was (or was not) effective in teaching basic skills?

a.	No response.	.04
b.	It was not effective because it lacked realism.	.12
c.	It was effective--miscellaneous reasons.	.20
d.	It was effective because it allowed visualization of the operations.	.24
e.	It was effective because it allowed hands-on practice.	.40

9. As opposed to using a workbook, how much did the interactive graphic simulations of the panel and tactical plot aid in learning?

a.	To a very great extent.	.09
b.	To a great extent.	.91
c.	To some extent.	.00
d.	To a little extent.	.00
e.	To a very little extent.	.00

10. As an aid to learning, the continual feedback provided on your performance was:

a.	Very effective.	.09
b.	Effective.	.63
c.	Somewhat effective.	.23
d.	Ineffective.	.05
e.	Very ineffective.	.00

11. How do you feel that this training capability will affect your later performance in operating the Data Link system when you are in the fleet?

a.	It will enable me to operate the Data Link system.	.14
b.	It will make it easier for me to learn the skills when I use actual S-3A components.	.86
c.	It will not affect my performance.	.00
d.	It will make it somewhat difficult to perform in the real situation.	.00
e.	It will make it very difficult to perform in the real situation.	.00

12. What specific aspects of this Data Link training did you like the most?

a.	No response.	.12
b.	Miscellaneous.	.04
c.	The hands-on practice.	.38
d.	It allows visualization of operations.	.19
e.	The similarity to actual equipment and operations.	.15
f.	The instructional characteristics.	.12

13. What aspects did you like the least?

a.	No response.	.12
b.	Miscellaneous.	.15
c.	The size and/or readability of the display.	.12
d.	System or software problems.	.38
e.	The display delay.	.23

14. How could this training be improved?

a.	No response.	.22
b.	Miscellaneous.	.14
c.	No changes needed.	.14
d.	Allow more time to study it.	.14
e.	Eliminate system or software problems.	.36

CBT Ratings

15. In comparison with other methods of learning, computer-based training was:

a.	Very enjoyable.	.28
b.	Enjoyable.	.67
c.	Neutral.	.05
d.	Boring.	.00
e.	Extremely boring.	.00

16. How do you rate computer-based training in relation to other training you have experienced?

a.	Outstanding.	.09
b.	Above average.	.67
c.	Average.	.19
d.	Fair.	.05
e.	Poor.	.00

17. What one thing do you like best about computer-based training?

a.	Self-paced instruction.	.29
b.	The novelty or way it keeps your attention.	.14
c.	The instructional characteristics.	.21
d.	The capability for hands-on practice.	.14
e.	The efficiency of CBT.	.11
f.	Interaction with the system.	.11

18. What one thing do you like least about computer-based training?

a.	No response.	.09
b.	Miscellaneous.	.23
c.	Not enough feedback or instruction.	.09
d.	It's tiring or boring.	.36
e.	The system or software problems.	.23

19. How much value would this lesson have to new inexperienced students learning the basic skills for Data Link operations?

a.	No response.	.05
b.	Much value.	.59
c.	Moderate value.	.27
d.	Low value.	.09

20. If you have any final comments to make about the PLATO IV system, the training materials, or computer-based training, please make them here.

a.	No response.	.73
b.	Miscellaneous.	.27

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